

DEVELOPMENTAL DYSPLASIA OF THE HIP MEDICAL TRAINER

BACKGROUND

Developmental dysplasia of the hip (DDH) is the most common abnormality in infants and relates to general instability, or looseness, of the hip joint. Currently, the cause of DDH is unknown, but there are some contributing factors that could increase the possibility, including laxity of the ligaments, properties of the bones, family history, an infant's womb position, and gender [1]. During the neonatal period (the first four weeks of an infant's life), diagnosis of DDH can be assessed with the Barlow and Ortolani procedures. The existing model used to practice these procedures lacks the bone mechanics and ligamentous structures associated with the movements.

BONE STRUCTURES

The team developed a neonatal sized prototype in Simpleware using computerized tomography (CT) scans of an infant. The CT scans contained a healthy hip (left hip) and a dysplastic hip (right hip). Using the modeling software SolidWorks, the team created a "Button" design to be able to secure the ligaments to the femur and pelvis. The left femur and pelvis bones with the implemented "Button" design for the prototype were 3D printed using polylactic acid (PLA). PLA filament was chosen for its cost, ease of use, and printing accuracy when compared to similar considered materials such as Acrylonitrile butadiene styrene (ABS) plastic or polyurethane.

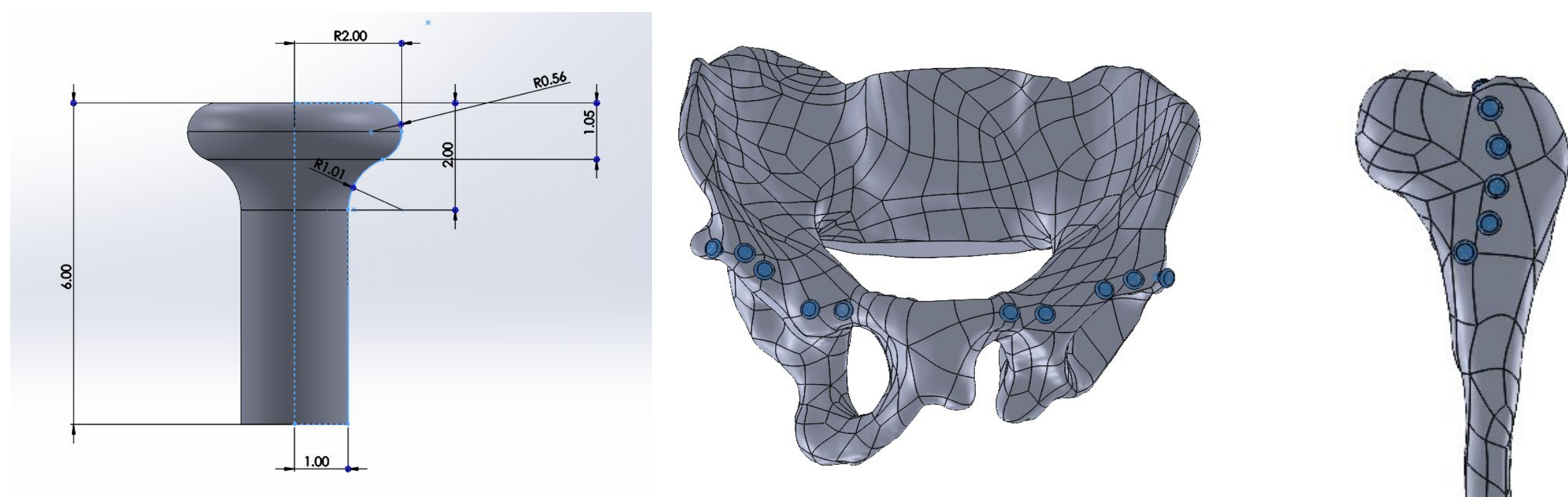


Figure 1: Dimensioned "Button" attachment design (left). Solidworks model of the neonatal pelvis (middle). CAD model of the left proximal neonatal femur (right).

LIGAMENTOUS STRUCTURES

Using the software CATIA, ligament designs were modeled based off 80% of the measured lengths between the "Button" attachments to take into account the pre-loading factor of ligaments. The three main ligaments of the hip joint were modeled using NinjaFlex thermoplastic polyurethane (TPU) due to its high flexibility and 65% elongation at yield. Table 1 shows the five different bundles of ligaments implemented.

Table 1: Ligament bundles.

Ligament Bundles		
Name	Quantity	
Superior Iliofemoral	1	
Inferior Iliofemoral	1	
Ischiofemoral	2	
Pubofemoral	1	



Figure 2: 3D printed ligament.

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ABSTRACT

Developmental dysplasia of the hip joint is the most common abnormality in infants. The exact causes of this abnormality are unknown but there are ways to detect and correct the issue, such as the Barlow and Ortolani maneuvers. The Barlow maneuver attempts to dislocate the femoral head with hip adduction and posterior translation while the Ortolani maneuver tries to relocate the dislocated femoral head with hip abduction and anterior translation. Improper training of these two procedures can decrease the chances of detecting this abnormality in infants, therefore, creating a proper model to practice performing these maneuvers on is important. The team is developing a model that will improve upon the existing model that is currently used. This will help to more accurately detect developmental dysplasia of the hip in infants so they can receive the proper care to correct the issue.

RESULTS

The pelvis and femur models were 3D printed using PLA at a 20% infill density and a triangle infill pattern. The ligaments were 3D printed using TPU at a 100% infill density.

Receiving feedback from Orthopedic Surgeon, Dr. Price, the team realized the femur bones fracture with little force applied. Currently, the team is experimenting with creating the femurs using TPU filament at various infills (20%, 30%, 40%, 50%) to achieve a more accurate feel of a neonatal femoral head and acetabulum when performing the Barlow and Ortolani procedures and with inserting a stainless steel rod to provide support.



Figure 3: Stainless steel rods used for experimentation at varying diameters.

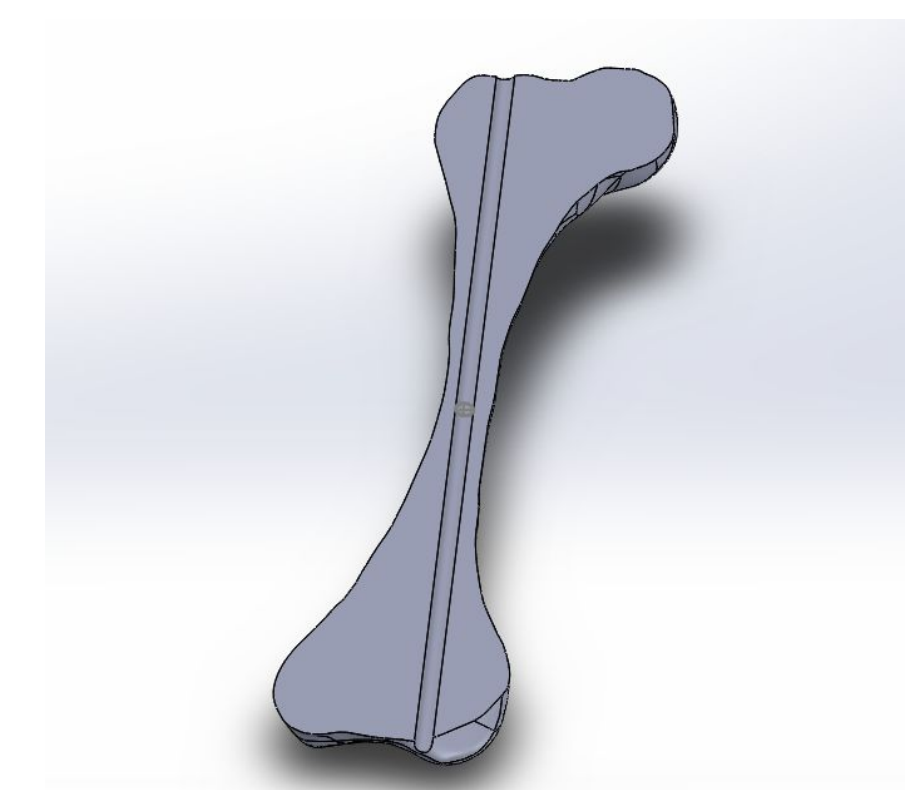


Figure 4: CAD model of the femur with the rod hole.

DISCUSSION

A major obstacle was the lack of literature on infant ligament properties. Multiple papers discussed the use of a scale factor to determine the properties of infant tissues [2]. Unfortunately, no confirmed scale factor for the infant hip ligaments was found.

CONCLUSION

The team designed and fabricated a prototype that shows the bone mechanics and ligamentous structures during the maneuvers. Improving this prototype will allow for better practice of the Barlow and Ortolani procedures. This will help detect DDH in infants more accurately.



Figure 5: DDH Medical Trainer prototype.

FUTURE GOALS

Currently, the team is looking to create a type of casing or mount for the model to rest on, as well as, determining which material should be used for the femur bones (PLA or TPU).

A Finite Element (FE) Model of the prototype was created to analyze the contact pressures and displacements that occur during the two maneuvers. The team is looking to use the results obtained from the FE Analysis to validate the ligament forces and properties necessary for the prototype. Pressure pad sensors will be placed in the acetabulum of the DDH Medical Trainer and forces will be applied to the femur mimicking those that occur during the two maneuvers. A simulation will then be ran on the FE model to be compared to the teams prototype.

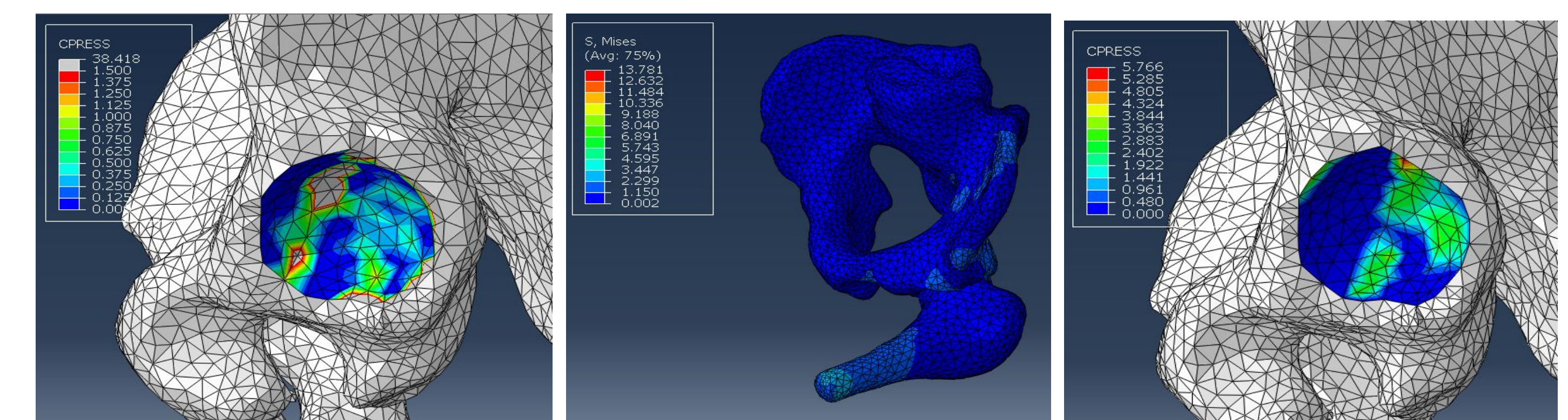


Figure 6: Contact pressures (left and right) and von mises stresses (middle) of the FE Model.

REFERENCES

- [1] *Causes of DDH*. Hipdysplasia.org. (2020). Retrieved from <https://hipdysplasia.org/developmental-dysplasia-of-the-hip/causes-of-ddh/>.
- [2] Jones, B. (n.d.). Development of a Set of Force Response Equations to Represent the Musculature in Infants to Study Development Dysplasia of the Hip. Retrieved from <https://stars.library.ucf.edu/honorstheses1990-2015/1868>

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